Although recognizedly imperfect and held subject to amendment after further investigations, this formula will be found to bring about much closer results than the simple summation method or any other modifications of it so far advanced.

The final formula which is to be brought out with further study, will take into consideration more accurate values for plant temperature, and give proper weight to the effect of wind velocity, humidity, and both the caloric and actinic value of sunshine.

In conclusion it should be stated that these studies are only preliminary to others which the author hopes to make with the aid of more accurate instruments and methods. It is realized that an enormous amount of research must be carried through before the final goal is reached and an exact formula established for expressing the complete relationship between climatic or weather conditions and crop production; and that this is only a minute contribution toward the desired end.

The valuable suggestions and assistance rendered by Drs. E. A. Bessey and R. P. Hibbard, by Profs. A. R. Sawyer, C. W. Chapman, and others of the Michigan Agricultural College, are gratefully acknowledged, as is also the assistance given by Mr. B. B. Whittier, observer, in making many thermometric readings.

SUMMARY.

The relation between weather and crop production is vital and important, but definite statements as to the exact relationships existing are lacking, for the most part, especially in regard to the rôle of temperature. In the latter respect we need a statement of the plant's thermal requirements and a method of evaluating air temperature in terms of its efficiency to meet these requirements.

The method most generally used has been called the summation process, consisting of simply adding together the mean daily air temperatures during the life phase of a crop, in order to find the thermal requirement. This produces widely differing results from year to year. The same process yields somewhat more consistent results if one employs maximum instead of mean temperatures; but the summation process is ineffective.

Van't Hoff's law, when introduced into the study by the exponential method, also fails to produce consistent results, mainly because it does not take into account the optimum temperature for growth.

Livingston's "physiological index" method of evaluating temperatures is based on a reasonable footing in that he used actual growth rates resulting from differing temperatures; but it does not produce much closer results when it is actually applied to the problem.

It is believed that the temperature of the plant itself should be given more consideration, as it is much warmer than the air when bathed in sunshine. Observations carried on at East Lansing during 1915 and 1916 show that this excess in temperature of the plant over the air in clear weather averages about 15 degrees, in partly cloudy weather 10 degrees, and in cloudy weather less than 1 degree (F.). Curves expressing plant growth rates and plant temperatures show parallelisms more decided than other temperatures observed, including maximum and mean air temperatures, soil temperatures, and readings of the "black-bulb in vacuo." A test of the number of heat units required to cause a cherry tree to blossom in the greenhouse and out-of-doors shows remarkably close results when plant temperatures are considered, but a consideration of air temperatures alone gives a wide variation.

A formula is evolved for determining the effectiveness of air temperature in promoting crop development, as follows: $T=t+15C+10P$, t being the sum of maximum temperatures above 42° during a certain period, after that amount has been subtracted from each temperature, C being the number of clear and P the number of partly cloudy days during the period.

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DAMAGE BY HAIL IN KANSAS.

By S. D. FLORA and C. L. BUSH.

[Dated: Weather Bureau Office, Topeka, Kans., Apr. 17, 1917.]

In Kansas damage by hail is most serious in the fields of growing wheat, and in the wheat-growing belt of the United States it is a widespread practice to insure against such loss by hail. It therefore seemed reasonable, to the writers, to expect to find that in this wheat belt there had been made a close study of the occurrence of hail. So far as they have been able to ascertain, however, no systematic collection of data relative to hailstorms in Kansas—the greatest wheat-growing State of the Union—has ever been attempted beyond the statistics of losses sustained there by the companies issuing hail insurance. This omission seems all the more striking in view of the fact that reliable estimates indicate hail-caused damage amounted to more than $6,000,000 during 1915 alone—an amount of damage many times greater than ever resulted from the tornadoes of any single year and probably greater than the average annual damage from unseasonable frosts. Yet both tornado and frost occurrences have been studied at length.

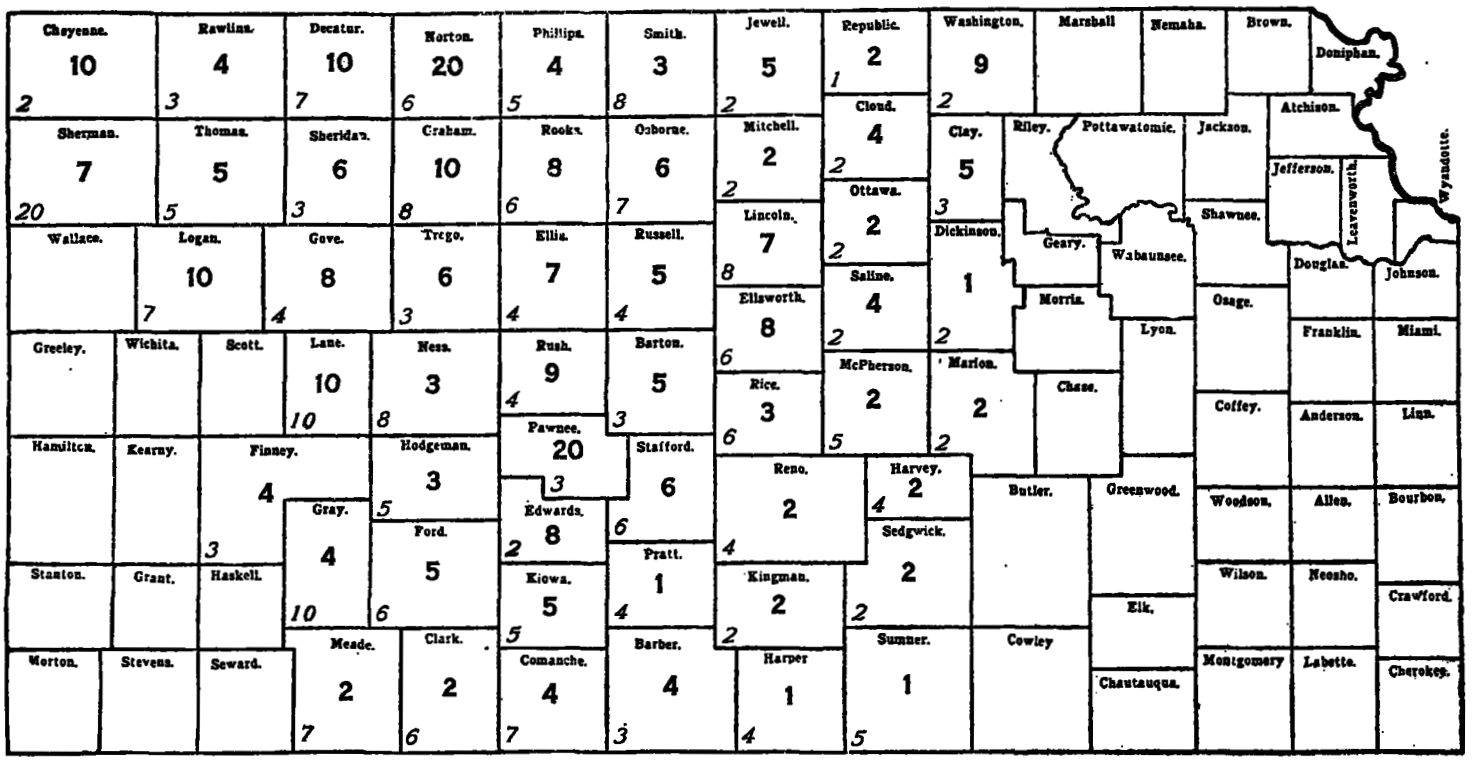

FIG. 1.—Percentage of wheat crop in Kansas damaged by hail during the past 18 years (by counties) as inferred from the records of the most important hail-insurance company of that State. Figures in italics give the percentage of the wheat crop of each county that was insured in this company.

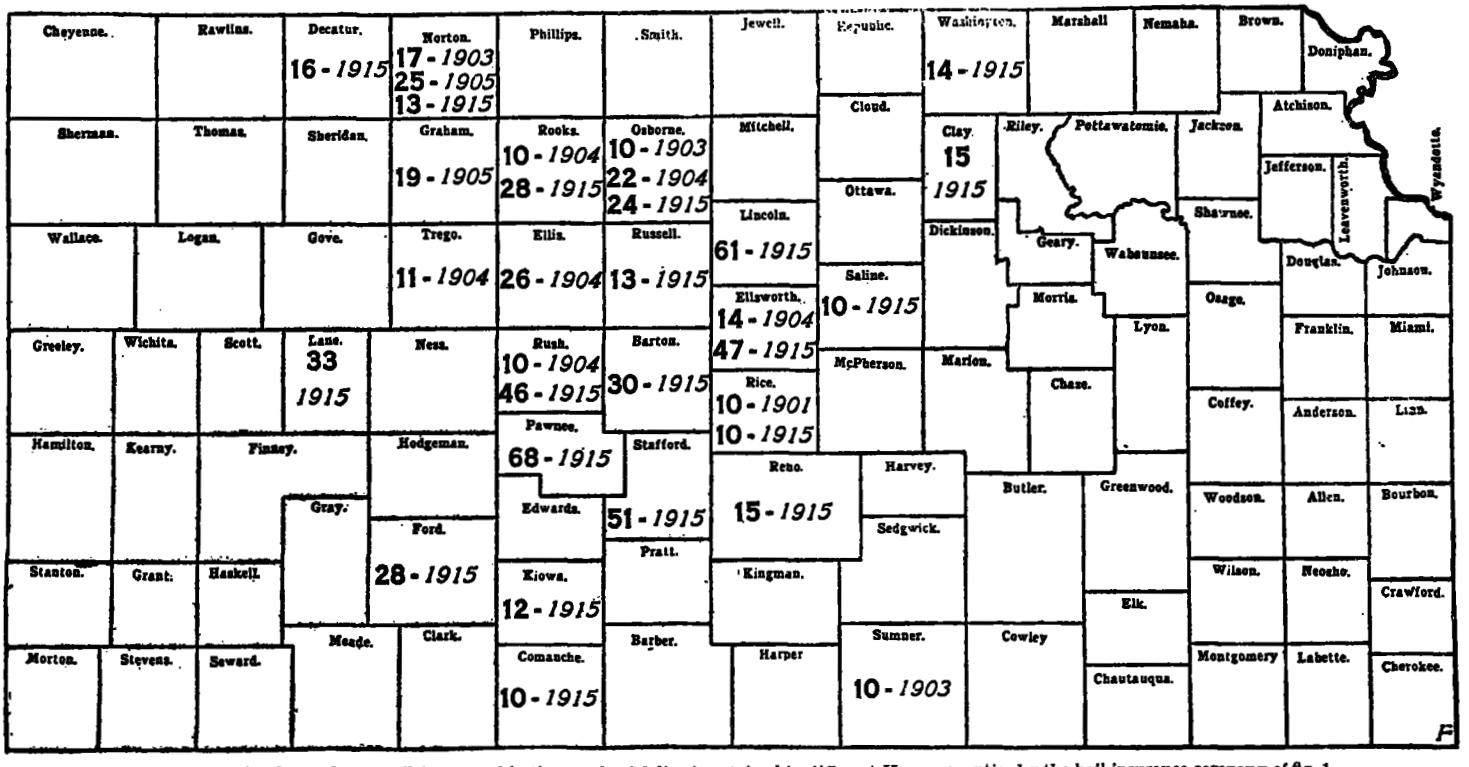

FIG. 2.—Heaviest losses due to hail (expressed in thousands of dollars) sustained in different Kansas counties by the hail-insurance company of fig. 1.

Practically the only record of loss due to hailstorms is that kept by the hail-insurance companies in their efforts to fix equitable rates for the different counties, and of these the records of but one company cover the State sufficiently and extend over a long enough period of time to give a reliable index of the probability of the occurrence of hail. This company has written almost as much hail insurance in Kansas as all other companies combined, its records showing that it has insured an average of approximately 3½ per cent of the total wheat crop of the State for the past 14 years. A study of its losses, which have been carefully compiled, should give an important clue to the distribution of the loss over the State from year to year.

The average annual loss by hail to the wheat crop in the principal wheat-growing counties of Kansas, expressed as a percentage, is shown in convenient summary in figure 1. The percentages there printed were obtained as follows: The total wheat acreage for each county was taken from the reports of the Kansas State Board of Agriculture. The total acreage insured in each county by the insurance company before mentioned, and the total loss sustained each year in each county by that company, were obtained from the latter. From these figures it was simple to compute the percentage of the total risk lost each year during the period of 18 years, 1899 to 1916, inclusive. Strictly speaking, the figures on the chart, figure 1, are the percentages of loss sustained by the *insured* crop, but it seems safe to assume that, without reasonable error, hail damage was uniform throughout the county, and therefore we present the figures as representing the best obtainable evidence of the damage due to hail in each county. Data for the less important wheat-raising counties have been omitted since the business done by the company there has hardly been sufficient to give a reliable average.

It is interesting to note that the percentage of damage in the extreme eastern counties for which data are available, is considerably less than that of the western. In fact the rate charged by this company for the western counties, as deduced from its tables of loss, is two and a half times that charged for the eastern, and the records of the company show it has lost money on its business done in the western counties while the business done in the eastern counties at the lower rate has paid good dividends.

Figure 2 shows all losses of $10,000 or more sustained by this company on account of individual storms, and serves to explain the abnormally heavy percentage of loss shown in figure 1 for a few counties such as Norton and Pawnee. The fact that most of these heavy individual losses have occurred in the central counties instead of the western, where the average for the entire period is highest, may be due partly to the heavier stands of wheat in the central portion of the State and partly to more frequent and less violent hail storms in the western portion. There are very few data, however, to support the latter contention.

Hail is so commonly associated with thunderstorms and thunderstorms with heavy rainfall, that it is somewhat difficult to understand why the probability of damage by hail increases toward the western portion of Kansas when both the average annual rainfall, and the rainfall for the crop-growing months in the western third of the State are less than half the averages for those periods in the eastern third. This anomaly is emphasized by Table 1.

TABLE 1.—*Losses sustained by hail insurance company in Kansas compared with departures of the July–August rainfall, 1899 to 1916, inclusive, for the State.*

Year.	Percentage of loss sustained by hail insurance company.	Departure from normal of total rainfall for July and August.
	Per cent.	*Inches.*
1899	1	+0.55
1900	2	−1.06
1901	2	−2.27
1902	3	+2.44
1903	4	+1.59
1904	7	+2.99
1905	9	+2.99
1906	2	+1.86
1907	5	+0.27
1908	6	+0.70
1909	5	+0.34
1910	1	−0.21
1911	¼	+0.99
1912	2	−0.01
1913	3	−4.94
1914	1	−0.77
1915	9	+3.90
1916	5	−1.96

While this table indicates that the damage by hail is not always proportional to the amount of rain that falls during the harvest months, July and August, the losses of dry seasons such as occurred in 1901, 1910, and 1913, have been small, while those of the notably wet harvest seasons 1904 and 1915 have been heavy; in fact, the season of 1915 brought failure to more hail insurance companies doing business in Kansas than any other year in the history of the State.

What causes this increase in liability of damage by hailstorms in the drier western counties of Kansas? This is an interesting problem that is worthy of future investigation.

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SCARF CLOUDS.

By CHARLES F. BROOKS, Ph. D.

[Office of Farm Management, Washington, July 25, 1917.]

(These notes were written immediately after the observations were made, and before having read anything on the phenomena. Therefore, my observations only substantiate the conclusions reached by previous writers mentioned in the footnotes.)—C. F. B.

The name "scarf cloud" has been applied in conversation, by Prof. W. J. Humphreys to a cloud which forms immediately over a rapidly rising cumulus dome and through which the rising cloud passes without hesitation.

On July 13, 1917, at Washington, D. C., the light easterly wind, clear air, and moderate humidity favored the growth of towering cumuli. By noon some had attained their limiting height, and were sending false cirrus sheets eastward. At about 4 p. m. some showers of very large drops bore witness to the rapidity of the ascending currents through which they fell. By 6 p. m. the air stratum where the cumulus clouds had been spreading their tops was well supplied with moisture, a fact which was marked by the scattered dissolving cirrus cirro-stratus, and cirro-cumulus clouds at this level.[1] At 6:22 a towering ebullient cloud in the north was seen to be surmounted by a thin "disk-cloud";[2] at 6:23 the

[1] Compare *W. J. Humphreys* in Bull., Mount Weather obs'y, Washington, 1909, 2:133–135. The "cirro-stratus" of the International cloud atlas, 1896, Pl. xii, fig. 23.

[2] This "disk cloud" is clearly the same as the usual "cap cloud" or "cumulus cap" whose origin was explained by C. Abbe in this REVIEW, October, 1906, 34:457, and yet earlier described and explained, among others, by Groneman in Meteorol. Ztschr., April, 1901, 18:176–177; Luke Howard, Essay etc., p. 5 & 10.—EDITOR.